

Phase I Project Summary

Firm: CFD Research Corporation

Contract Number: NNX10CE27P

Project Title: A Miniaturized Sensor for Microbial Monitoring of Spacecraft Water Environment

Identification and Significance of Innovation:

The presence of the pathogenic microbes in closed spacecraft environment is well acknowledged to pose a significant risk to astronaut health and performance and compromises space exploration for extended periods. Accurate microbial monitoring of water environment is of paramount importance to ensure proper functioning and control of the Life Support Systems (LSS). Current methods are time-consuming and labor-intensive entailing extensive training in a series of complicated operations (e.g., sample preparation, culture, and analysis). The devices used are bulky, consumable-hungry, and consequently, ill-suited for spacecraft deployment.

The overall objective of the project is to develop a novel miniaturized, automated, label-free sensor for microbial monitoring in spacecraft water environment. The research harnesses state-of-the-art electrokinetics, impedance-based detection, and microfabrication techniques and combines novel sample preparation and detection technologies. Key innovations that mark this effort include:

- A milli-fluidic preconcentrator to enrich microbe samples for improved sensitivity in detection
- A microfluidic dielectrophoretic focuser to allow precise microbial manipulation
- A microfluidic impedance-based cytometric detector to enable label-free detection
- Integration of the above components into a sensor platform for fully automated, in-line operation

The research effort is intended to establish rapid 'detect-to-warn' capability for water monitoring in spacecraft environment as well as to render a sample ready for downstream confirmatory assays (in terms of sample volume and concentration). The device will provide NASA a powerful tool for real-time microbial detection and identification, and greatly aid in NASA's efforts to minimize microbial exposure/infection hazard, develop countermeasures, and ensure proper functioning and quality-control of life support system in spacecrafts, space shuttles and space stations.

Technical Objectives and Work Plan:

The overall projective of the project is to develop a novel miniaturized, automated, label-free microbial sensor for water monitoring in spacecraft environment. Phase I goal is to demonstrate the proof-of-concept of the water monitoring sensor, and the effort will focus on the development of the milli-fluidic and microfluidic components of the sensor cartridge. Specific Phase I technical objectives and work plan are:

- Formulate specifications for the sensor cartridge
- Conceptualize milli-fluidic and microfluidic component design(s), viz., the lateral-flow preconcentrator, DEP focuser, and impedance-based sensor
- Fabricate the components using state-of-the-art microfabrication techniques
- Experimentally test, characterize and demonstrate functional components
- Develop plans for optimization and integration of the components into a single cartridge

Technical Accomplishments:

All Phase I project goals were successfully addressed, including:

1. Multi-physics simulations enabled virtual design of microsystems. Computational prototyping was performed to develop designs of critical sensor components, i.e., cross-flow preconcentrator, dielectrophoretic focuser and microfluidic impedance sensor.
2. Rapid microfabrication and prototyping. Single component prototypes were fabricated and engineered using machining and lithography based microfabrication processes. COTS technology was leveraged where possible for short turnaround times.
3. Cross-flow preconcentration of bacterial cells and particles. The Gen1 preconcentrator design was experimentally tested with **Fab5 bacteria** and lab demonstrated to meet all Phase I design specifications with **concentration enhancement of approximately 14X** using a single preconcentrator unit.
4. Focusing and alignment of bacterial cells and particles. Dielectrophoretic focuser experiments were successfully undertaken, and focusing and manipulation of Fab5 bacterial and PSL particles was clearly demonstrated. Performance of multiple electrode designs and electric field settings were characterized.
5. Impedance detection of bacterial cells and particles. The micro-pore sensor with smallest feature size of 3 μm was designed, microfabricated and experimentally tested. A critical element of the impedance detection – sequential traversal of the particles and cells through the micro-pore was optically observed which confirms the feasibility of the micro-pore based design.

The technical accomplishments in Phase I **directly establish the proof-of-principle of our sample preparation and detection technologies for spacecraft water environment monitoring.**

NASA Application(s):

The end product of the proposed SBIR effort will be a first-of-its-kind, compact, low-cost, label-free, fully automated and integrated microbial sensor device for water monitoring, and establish rapid 'detect-to-warn' capability in spacecraft environment

and render a sample ready for downstream confirmatory assays (in terms of sample volume and concentration). The device will provide NASA a powerful tool for real-time microbial detection and identification, and greatly aid in NASA's efforts to minimize microbial exposure/infection hazard, develop countermeasures, and ensure proper functioning and quality-control of life support system in spacecrafts, space shuttles and space stations. The device will be of direct use to NASA's ground-based research facilities and amenable for space deployment as well.

Non-NASA Commercial Application(s):

The proposed sensor technology will have direct commercial value in both federal and civilian sectors. The device can be used for US Navy shipboard wastewater monitoring or on-field assessment of water quality during military mission. The anticipated civilian applications include:

- Pre-clinical and Clinical Diagnostics (e.g., microbial detection in body fluids)
- Public & Natural Water Monitoring (e.g., hospital & health site, recreational and drinking waters)
- Industrial Wastewater Surveillance (e.g., water treatment and food-processing plants)

Name and Address of Principal Investigator:

Yi Wang, Ph.D., CFD Research Corporation, 215 Wynn Drive, Huntsville, AL 35805

Name and Address of Offeror:

CFD Research Corporation, 215 Wynn Drive, Suite 501, Huntsville, AL 35805